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STRUCTURE AND DEVELOPMENT OF THE BRAIN:

A LECTURE

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BY

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STRUCTURE AND DEVELOPMENT OF THE BRAIN.*

When I was invited to deliver a lecture under the auspices of this Association, it occurred to me that there was no topic taken from the science of Anatomy more likely to interest the audience than an account of the progress recently made in the investigation of the structure and development of the brain—as the organ in which all those vital processes are carried on by which we are brought into relation with the world around us—the centre to which all impressions from without are conveyed so as to give rise to our feelings or sensations—the source of origin of the impulses which cause our various active movements—and the seat during life of our intelligence or mind, that is, of our consciousness and memory, our feelings, emotions and passions, our will, our thoughts, judgment and reasoning power.

In adopting the title of "Evolution of the Brain," it appeared to me that I could best lay before you the groundwork upon which our views as to the relation of the structure and functions of the organ must mainly rest, by calling your attention to the principal facts which have been ascertained in the following divisions of our subject:—

1. The origin, early formation, and development of the brain in the embryo.

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* This Lecture, when delivered, was illustrated very fully by numerous large diagrams, drawings, and specimens; but as it has been found impossible satisfactorily to reproduce these in figures within reasonable limits in this publication, it has been deemed expedient to omit them entirely, trusting that the statement in the text may be sufficient to indicate the Lecturer's meaning. The reader is reminded that the Lecture was delivered so long ago as in February 1877.

2. The differences in its form, size, and structure among animals.

3. A comparison of the brain of man with that of the animals most nearly resembling him, such as the anthropomorphous apes; with some remarks on the varieties of form and size observed in the brain among different individuals and races of man.

4, and lastly. An attempt to form a scheme or plan of what may be called the architecture and mechanism of the brain, or, in other words, to trace the relation and connection of its various parts, not merely by the study of the arrangement of the larger and more obvious masses, but also by the microscopical investigation of its minute structure, which makes us acquainted with the organised nature of the texture and the properties of the materials employed in its construction.

Such a view of the structure or anatomy of the brain would naturally be accompanied or followed by an account of its functions, but, as may be readily understood, so extensive and interesting a series of topics could not with advantage be discussed in the present lecture, which I shall regret the less, that I believe my colleague Dr. M'Kendrick will more ably undertake this difficult task in the next winter course. At present therefore I shall not attempt to do more than to show the bearing which ascertained facts in the anatomy have upon the knowledge and investigation of the functions. Before proceeding with the special subjects indicated, let me first give you a very short general account of the brain of man.

This organ, filling, along with its covering membranes and blood-vessels, completely the cranial cavity of the head, consists of a large mass of soft and extremely delicate animal tissue, which, from its being of a similar nature with that composing the nerves, is named the nervous tissue or texture.

The size of the human brain is subject to great variation. By the comparison of a very large number of brains, it has been found that the average weight of the brain in a grown man of this country is about 3 lbs. avoirdupois, or more precisely 49½ oz.; its bulk is from 80 to 85 cubic inches; and the size does not differ widely from this among the principal European nations.

Much the larger portion of this mass forms the greater brain or cerebrum of anatomists, which you will remark, from the model I show you, is so large, when viewed from above, as completely to cover all the other parts. Below the hinder part of this comes the cerebellum or smaller brain, forming little more than a tenth of the whole, while below this and towards the middle are certain parts of smaller dimensions which connect together the cerebrum and cerebellum, and unite both of them to the spinal marrow. These parts are named the cerebral peduncles or pillars, the bridge of Varole, and the oblong medulla. The last-named part, or medulla oblongata, passes insensibly at the junction of the head and neck into the spinal marrow, a long somewhat cylindrical column, which is in its structure of the same general nature as the brain.

From both of these parts (as will be seen from the drawings exhibited) there arises a series of nerves in pairs, which pass to be distributed by subdivision, or rather separation, of their fibres, in almost all the organs of the body; and thus it appears that by their anatomical or structural relation, as well as by their functional association afterwards to be adverted to, the brain and spinal marrow constitute together the great centre of the nervous system, or cerebro-spinal nervous centre.

The arrangement now mentioned belongs to man in common with all vertebrated animals, and may be regarded in some measure as the basis of the form of the skeleton in vertebrates, and of the morphological character which pervades the organization of all the classes in that division of the animal kingdom.

In this organization you will observe that two remarkable features present themselves: 1st, the successive repetition of parts essentially similar in a linear series along and round a central axis; and 2nd, the precise similarity of the parts on each side (that is right and left) of a middle line or plane, while there is not the same correspondence between those situated before and behind. Longitudinal serial repetition and bilateral symmetry are therefore anatomical characteristics of the main parts of the nervous system in vertebrate animals, and you will see from the figures with what remarkable regularity these characters are maintained both in the central masses and in the distributed nerves.

Of the regular nerves now referred to, there are twelve pairs connected with the brain, and thirty-one pairs with the spinal marrow.

By physiological investigation, it is known that the properties of the fibres within the nerves are of two different kinds, viz., sensory and motory, or such that when a nerve is stimulated certain fibres transmit changes in one direction, say from without inwards, while other fibres are connected with the manifestation of vital phenomena in the opposite direction, or from within outwards.

In all the spinal nerves, and in a few of those proceeding from the brain, the fibres of both endowments are enclosed in the same nervous trunk and branches, but in other cerebral nerves all the fibres within one nerve are of the same kind of endowment, that is, either entirely sensory or entirely motory. But in the case of all the spinal nerves, these two sets of fibres, though mixed together in the main nerves, are completely separated at their roots a short distance before these enter the spinal marrow, and thus we have the opportunity, by operating upon the roots, of distinguishing their different properties. We owe to Sir Charles Bell the first experiment which clearly pointed out a difference of function between them, now well known as the afferent or sensory function of the hinder roots, and the efferent or motory function of the anterior roots—a fact which forms the basis of all modern researches concerning the nervous functions.

These nerve roots, both cerebral and spinal, penetrate separately for a certain depth into the central organs, and there pass into some intimate organic union and communication with their substance, and this we name the real or deep origin of the several nerves.

The peripheral nerves are composed of very numerous fibres bound together in a common sheath, but yet so arranged that each fibre runs its course from end to end almost without division, and entirely without union or direct communication with those lying beside it.

Although nervous and electrical action are probably very different, yet the individual fibres of the nerves may not be inaptly compared to the copper conducting wires of an electric or galvanic battery, and especially to such as are insulated by a covering of gutta percha, for it appears that a certain finer inner filament, or a bundle of such fine filaments, is the more immediate seat of nervous action or transmission of nervous influence, while these filaments are surrounded individually or in bundles by materials of a fatty and membraneous nature, which take no part in the nervous action.

In the brain and spinal marrow on the other hand, as also in the so-called ganglia or nerve-knots, which are in some measure central nerve organs, the nervous texture occurs in two very distinct forms. One of these is of a whitish and fibrous nature, and indeed very similar to that just now described as belonging to the peripheral nerves; the other is composed of minute corpuscles of peculiar structure, similar to the microscopic bodies now recognised by anatomists as organised cells; and it is probable that these two kinds of nerve texture are everywhere in direct union or communication with each other in the central organs of the nervous system.

The fibrous component of the central organs is generally held to perform the same office in them as in the peripheral nerves, that is, one of transmission of nervous action from one part to another; but the corpuscular or cellular elements have probably other functions which may be considered to belong specially to central organs, those namely of establishing communication between nerves of different endowments, of transferring in this way nervous action from one nerve to another, and even it may be of originating influences which excite or otherwise act upon the nerves which are in connection with them.

From this it appears that the corpuscular or cellular nervous element is to be looked upon as the peculiarly central one, even although the fibrous transmitting or internuncial nerve substance also enters into the composition of a central organ.

With reference to these two components of the nervous substance in the brain and spinal marrow, it only farther remains to be stated that, though often much mixed up together, they are generally to be distinguished by a difference of colour, the part in which the fibrous structure prevails being of a brilliant creamy whitish colour, and receiving the name of medullary or white, that in which the cells abound being of a reddish grey colour, and usually called the grey or cineritious matter. In the brain of man and the higher animals, there are three situations in which the grey or corpuscular elements are accumulated in greatest quantity, viz.: 1st, at the places of origin of the roots of the several cerebral nerves; 2nd, in certain large and distinct masses placed in the deeper region or near the base of the brain, forming what have been called the basal cerebral ganglia, of which the corpora striata, the thalami optici, and the corpora quadrigemina are the principal; and 3rd, in a layer occupying the surface of the cerebrum and cerebellum, where from its being thrown into a plaited or frilled form, in what are termed the convolutions of the cerebrum and the laminæ of the cerebellum, a much larger quantity of the grey substance exists than if it had been a simple or plane bounding layer.

I need scarcely say that the brain of man, as I have now briefly described it, is a very different organ from that of a fish or a reptile, or even from that of birds and many quadrupeds, as a glance at the series of drawings representing the brains of some of these animals will at once convince you. But in now proceeding with the discussion of the topics which are to form the special subjects of my lecture, it will be my object to show you that, notwithstanding the wide differences which are apparent in the form and structure of this organ in man and the various vertebrated animals, there undoubtedly exists a general plan of remarkable uniformity upon which it is constructed in them all.

I. We shall first consider the process by which the brain originates in the embryo, and the changes of evolution or development by which it attains to its perfect condition.

Like all the other organs of the body, the brain takes its origin in the germinal part of the egg by a gradual process of transformation of the organised elementary particles or cells composing the germ, and is gradually built up and moulded into shape by the multiplication of these formative cells, their individual differentiation and their arrangement or grouping in new combinations. There is nothing at first, then, in the form or structure of the egg or its germ, which has any semblance of the future brain or other organs. They are entirely of new formation, and the process by which they come into first existence, and gradually attain their complete form and structure, is not by any means, as was once supposed, one of mere unfolding and coming into sight of parts previously existing, though too small or obscure to be perceptible, but one of entirely new combinations of the organic elements. The brain therefore presents at its origin a totally different form from that which belongs to its complete state, and goes through a number of transformations, both morphological and textural, in the passage from its simplest primitive condition to the adult form and structure.

It may not be out of place to dwell here for a short time on the nature and source of the formative substance from which the primitive parts of the embryo take their origin. The formative part of the egg, which is the source of all new production, consists of a flat expansion or layer of protoplasmic cells, called the blastoderm or germinal membrane, and this membrane has itself arisen by a very remarkable process of self-division and consequent multiplication occurring in the protoplasmic cells, of which it is made up; so that, if we trace back the steps of this process, we shall be conducted at last to a single germinal cell, from which the numerous progeny of blastodermic cells has been derived.

It is now known that this descent of the formative cells of the blastoderm from the original germ-cell, by a process of cleavage or multiplication, is a universal phenomenon in the first production of animals; and as all the organs of the new animal are formed from the blastodermic cells, it follows that they are all derived from the original single microscopic germ-cell. The brain, then, with all its complicated construction and delicate and intricate minute texture, and all its wonderful functional activity in connection with feeling, action, and thought, has originally sprung from a part of the cell-progeny of the original germ-cell of the egg, and all the qualities, powers, and properties, which this organ possesses by hereditary transmission, must have entered it by means of the extremely minute particle constituting the first germ-cell of the egg.

I can believe that some will be disposed to ask here, how is it possible to observe such things? for I have stated only that which is matter of observation; and as I cannot stop to explain everything, I will only say in a word that it is mainly by the investigation of the changes during incubation of the egg of the common fowl or other birds, that the observation of the origin of the first traces of embryonic formation has been made, but that supplemental observations, both in quadrupeds and in many of the lower animals, leave no doubt whatever that the main steps in the process are similar throughout all the classes of the vertebrate division of animals, and that there is even sufficient evidence before us to prove that the process is essentially the same in the human species.

And now, returning to the subject with which we are more immediately occupied—as I must not attempt to describe the whole process of cerebral development—I will endeavour to select some of the more prominent facts, and will trust to your gathering more of the details from an inspection of the illustrations which are before you.

In the first place, when the embryo chick, or rather the thickened plate of formative tissue of the blastoderm which represents its earliest trace, is about a tenth of an inch in length, and in the course of the first day of incubation, there is gradually formed, along with a median longitudinal thickening of the plate, a median linear depression or groove, running through the greater part of the plate. The side walls of this groove now thicken more and more, and thus rise upwards from the plane surface; and, somewhat later, the two ridges thus formed coming to arch over the groove, approach each other and finally coalesce at their margins, first towards the middle and later all along, so as to enclose a canal, constituting the walls of the simple cerebro-spinal cavity, and the rudiments of the brain and spinal marrow contained within them; and we very soon perceive a widening of this canal at the end which is afterwards found to be occupied by the brain.

Now it is important to note that it is solely the uppermost of the layers of the blastoderm which is at first concerned in thus laying the foundation of the great nervous centres; and further, that as the rest of this upper layer, extending outwards from the seat of the primitive groove and canal now described, is entirely devoted to the formation of the epidermis or cuticular covering of the embryo, there is actual original continuity of formative tissue between the cuticle and the great nervous centre. In fact, we can see the commencement of thickening, by cell multiplication, in the deeper part of the layer, preparatory to the formation of the cerebral and spinal rudiments, before the canal containing them is shut in, and this deeper layer has therefore been distinguished from the superficial or corneous by the name of nervous layer.

Simultaneously with the deposit and enclosure of the first rudiments of the great nervous centres, another important phenomenon of vertebral development demands our attention, viz., the appearance along the sides of the cerebro-spinal canal, and in the thickness of the ridges which have enclosed it, of a series of transverse strongly marked divisions, beginning with only one or two, in what corresponds to the region of the neck, but speedily increasing in number in a direction backwards or towards the trunk and tail end of the embryo. This cross cleavage of the primitive embryo, which does not at first affect the cephalic portion, but belongs only to the trunk of the body, is the indication or the precursor of that serial division or metameral repetition of parts, which is ever afterwards characteristic of the vertebrated form of the animal. It is not, however, exactly a division into the future vertebral pieces of the skeleton, but rather the forecast of a transverse division into segments, each of which comprises the elements of formation of the pairs of spinal nerves, the bones and muscles, and other parts belonging to each zone of the body. These divisions have therefore the morphological nature of segments of the trunk of the body.

A third phenomenon may also be stated as closely related to the formation of the first rudiments of the vertebrate embryo, in the appearance of a median cellular column below the greater part of the cerebro-spinal canal, and in the place afterwards occupied by the bodies of the vertebrae. This is the chorda dorsalis or notochord, an elementary and probably only a transitory cellular structure, round which the cartilaginous and bony substance of the vertebral bodies is afterwards deposited, and of some significance in the history of morphology and development, from its constancy and its intimate relation to the rest of the vertebrate structure.

The embryonic rudiment therefore presents, from its earliest appearance, features which are manifestly characteristic of the vertebrate organization; and these are, as it were, moulded round the great nervous centre, having as its earliest form that of an elongated tube of formative tissue dilated at its cephalic or cerebral end, and cylindrical throughout its spinal or trunk portion. This neural axis or centre arises by involution of a part of the upper or outer layer of the blastoderm, and is placed immediately above that primitive axial column, the notochord, which occupies the centre of the future spinal column of the skeleton.

Confining our attention now to the cephalic or cerebral portion of the nervous centre, one of the first important changes which occurs in its early development consists in an alteration of its simple pyriform shape into that of three vesicular dilatations, with intervening constrictions in the wall of the primitive brain. These three dilatations have been named the first, second, and third primary encephalic vesicles, and we shall now advert to the manner in which they give rise to the typical constituent parts of the brain.

Of the three vesicular dilations now mentioned, the second or middle one remains comparatively unchanged, and may even be traced to a persistent part of the adult brain. It forms the mid-brain or mesencephalon, and corresponds most nearly with that part of the adult brain which receives the name of the fourfold bodies, or corpora quadrigemina.

A part of the first and third vesicles may also be traced as persistent, the first in what is called the optic beds or thalami, and the third in the medulla oblongata which joins the spinal marrow; but both are greatly modified by the development of other parts in connection with them. For, in the first place, on either side of the anterior primary cerebral vesicle, there takes place a wide projection or dilatation of its wall, accompanied by a corresponding modification of the outer wall of the head, which is connected with the formation of the first rudiment of the nervous part of the eyes or retina; and, in the next place, there are formed, by extension forwards from the same anterior primary vesicle, two additional vesicles which become afterwards the cerebral hemispheres.

In connection with the third primary vesicle again, the first rudiment of the cerebellum makes its appearance by an arched thickening of the medullary wall, which stretches across the upper part of the vesicle immediately behind the middle one.

Thus the tripartite form of the primary brain is rapidly modified into one in which five parts are distinguishable in a series from before backwards, and as these parts exist in the brains of all vertebrate animals, and constitute the principal basis of formation of the permanent brain structures, they are regarded as typical, and may be enumerated under the following designations, viz.:—

1. The anterior vesicles becoming double at an early period, developed by extension from the first primary vesicle, and named *Fore-brain* or *Prosencephalon.*

2. The part of the first primary vesicle which remains as optic thalami, and which may be called the *Inter-brain* or *Diencephalon*, or the *Thalamencephalon.*

3. The second primary vesicle holding a middle place, and therefore named *Mid-brain* or *Mesencephalon.*

4. The cerebellum developed behind in connection with the third vesicle, and thus receiving the name of *Hind-brain* or *Epencephalon.*

5. The remaining part of the third primary vesicle which persists as medulla oblongata, and being lowest of all, is called *After-brain* or *Metencephalon.*

Had our time permitted it, I would gladly have explained to you in detail the steps by which, out of these five fundamental divisions, the various parts of the brains of different vertebral animals come to be formed; but as this cannot be done, I must content myself with a reference to some of the more important of the phenomena, keeping strictly in view the relations of the five fundamental parts already mentioned, but adverting more particularly to the cerebrum and cerebellum which attain very large proportions in man and the higher animals. In doing so it will be expedient, for the sake of greater simplicity, to state the developmental changes under the several heads of the modification, in form, size, and position in each of the parts, caused, 1st by the accumulation in certain parts of large quantities of new substance; 2nd, by the contraction, expansion, or other changes of the internal cavities; and 3rd, by textural alteration or differentiation. The two first series of changes may, in a great measure, be considered together; and it may be well, therefore, to say a few words here of the nature of the internal cavities of the brain, or so-called ventricles which have not been previously mentioned.

It has already been stated that, in the first form presented by the cerebro-spinal centre, there is a general internal cavity enclosed by the wall of primitive nerve substance of which it is formed, and we shall find that the permanent ventricles or internal cavities of the brain are only the persistent, though greatly altered, conditions of certain parts of the original simple tubular cavity.

Within the whole of the spinal part of the cerebro-spinal nervous centre, the canal comes to be reduced in the progress of development to almost microscopic size by the gradual encroachment of the solid substance of the spinal marrow which completely surrounds it; but in the cephalic portion of the primitive nervous tube much greater variety of changes occurs. Thus, to begin with the part next the spinal marrow in the region of the medulla oblongata and cerebellum, a transverse widening of the internal cavity in a flattened rhomboidal form, gives rise to what is called the fourth ventricle. In the mid-brain, again, the size of the cavity is suddenly reduced by the increased solidity of the surrounding substance to the condition of a narrow passage, which is prolonged forwards till it reaches the region of the thalami optici, thus forming the aqueduct of Sylvius of anatomists. Within the thalamencephalon the internal cavity is again dilated and deepened, and forms the third ventricle in the site of the first primary vesicle, which was originally the foremost part of the embryonic brain. But the two cerebral hemispheres, it has already been stated, are developed by an expansion forward of the wall of this first primary ventricle; and as this expansion becomes double, and each hemisphere comes to be occupied by a prolongation or extension of the general ventricular cavity of the primitive brain, the two cavities thus formed constitute the so-called lateral ventricles of the brain, and their common communication with the third ventricle is the aperture called foramen of Monro. This is an interesting fact in connection with the morbid dilatation of the ventricular cavities which occurs in the disease of water in the head or hydrocephalus, which sometimes takes place to such an extent as to expand the whole brain into an enormous bladder, with comparatively thin walls of brain substance.

From what I have previously said, it must have been seen that the substance forming the wall of the primitive vesicular brain is nearly of equal thickness throughout; but in the course of development there soon takes place a great change in this respect. Some parts of the wall, especially on its upper side, becoming relatively thinner, so that the nervous substance is even entirely lost, or, as it were, worn through, and the internal cavity opened up as far as the covering membranes; while other parts of the wall, especially in the lower and lateral regions, undergo a great proportional thickening by the growth of their material, and thus not only are certain of the fundamental vesicles expanded in their dimensions, but new parts are also added in connection with them.

It is also necessary to advert here to another kind of change which accompanies, and we might almost say determines, the mode of development of the head and brain—I mean the adhesion of the brain at certain places to the interior of the cranial cavity, which, when elongation of the whole and different relative expansion of some of the parts take place, is the cause of peculiar inflections both of the brain itself and of the cranial wall.

The most remarkable change of this kind occurs at a place which is immediately below what is originally the foremost part of the primitive brain, in a narrow prolongation downwards of the first primary vesicle, termed the infundibulum, where the brain is, as it were, pinned down to that part of the cranium which is afterwards occupied by the pituitary gland in the so-called "Turkish saddle." Now, the infundibulum of the brain is in all animals united with the pituitary gland at this place, and the union so effected seems to exercise some important influence on the whole form and development of the head; for while the expanding hemispheres of the brain become subsequently projected forward with the forehead, and upward and backward with the vault of the cranium, the original first vesicle or thalamencephalon remains adherent to the base of the skull, and thus is caused a bending of the whole skull round this point, which determines much of the later position and direction of the surrounding parts both of the cranium and face.

In endeavouring to trace further, in the briefest possible manner, the successive steps by which the fundamental parts of the brain are developed into those of the fully-formed organ, let us begin from behind, and take first those which preserve most nearly their earlier or embryonic form and relations.

1. In the part of the fifth fundamental vesicle which becomes the medulla oblongata, we observe at a comparatively early period of fœtal life a great difference in the growth of nervous substance in the upper and lower part; and in the former, as already noticed in connection with the fourth ventricle, so complete an atrophy, or want of new deposit, that the wall gradually thins away and disappears as far as the covering membranes, so as to open up the cavity of the fourth ventricle in that direction.

In the lower and lateral parts, on the contrary, a rapid and great increase of the solid nervous substance takes place, which leads to the formation of the constituent strands of white substance with their accompanying contained nodules of grey matter, such as the anterior pyramids, the olivary, and the restiform bodies, with the posterior pyramids.

2. The vesicle, which we have termed mid-brain in the

embryo, retains for a considerable time the most prominent place among the five fundamental encephalic divisions, and from its superior size, as well as the upward bending of the head, gives rise to a strongly marked projection of the part of the head which it occupies. It is at first single, and is occupied internally by a portion of the general ventricular cavity; but in the course of the middle third of the period of development it undergoes a great change of relation by the superior relative development of other parts, and is itself greatly altered by internal processes of growth. Thus it becomes divided first into two by a median depression on its upper surface—constituting the corpora bigemina of a certain fœtal stage and of animals up to the class of birds inclusive—and by a subsequent transverse groove is again subdivided, so as to show superiorly the fourfold character which has given to these bodies, in man and quadrupeds, the name of corpora quadrigemina.

By the great increase of deposit of the nerve substance, both white and grey, in these bodies and below them, the ventricular cavity (as previously stated) is gradually more and more contracted till it is reduced to the narrow tubular form of the aqueduct of Sylvius.

In the base of this fundamental part of the brain, there are found on either side the large masses of white or fibrous nerve substance, termed crura cerebri or cerebral peduncles, which form a principal means of union between the medulla oblongata below and the cerebral hemispheres above.

3. In connection with the thalamencephalon, or that part of the primitive brain which was originally placed farthest forward, the cerebral hemispheres arise at an early period by an extension forward and upward of the wall of the first primary encephalic vesicle, in a manner afterwards to be specially referred to. At present we have to do only with the lower and back part of this vesicle which remains as the inter-brain or thalamencephalon, in which several important changes deserve our attention.

a. First of all, the largely increased deposit of solid nervous substance in the lower and lateral parts of this division of the primitive brain, on each side of the ventricular cavity, forms the foundation of one pair of the great cerebral ganglia—viz., the thalami optici, with which the original pedicles of the optic nerves are connected, and these are separated by the cavity of the third ventricle, except at the place where they are brought into union by the grey commissure.

b. The prolongation downwards of the thin cerebral wall, with the cavity of the third ventricle within, in the shape of a funnel, the infundibulum, and the union of this, already referred to, with the pituitary body or hypophysis cerebri; and

c. The opening up, so far as the nervous wall is concerned, of the ventricular cavity in its upper and anterior part by a thinning process, nearly of the same nature as that previously mentioned for the fourth ventricle, and the development in the hinder part of the upper wall of that remarkable appendage to this part of the brain, the pineal gland, the Epiphysis cerebri, held by Descartes, on purely hypothetical grounds, to be the seat of the thinking principle. The remarkable constancy of the two bodies now mentioned (pituitary body and pineal gland), and the uniformity in their respective structure and mode of origin in all animals, from man down to fishes, constitute a set of important anatomical facts which are of doubtful interpretation, and require further elucidation from the history of development.

4. The cerebellum, or hind brain, which forms the fourth division of the primitive brain, as enumerated from the front, begins in the forepart of the third primary encephalic vesicle, by the growth of a bridge of nervous matter over the remainder of the vesicle, which, as already explained, forms the medulla oblongata and fourth ventricle. The cerebellum is at first a single and median lappet, but, its lateral parts afterwards increasing, it comes to consist, in more advanced stages of development, of median and lateral lobes. As these last increase a lower bridge of nervous matter crosses the base of the brain between them, and unites them by a sort of commissure. This is the pons Varolii, or mesocephalon, or nodus cerebri of anatomists.

The later development of the cerebellum is attended with the formation of deep furrows in its surface, dividing it into plates, and the distinction of the white substance within, and the peculiar grey or cellular layer externally, the disposition of which over the subdivided laminæ of the white gives, in a vertical section, that remarkable appearance which has received the name of arbor vitæ.

5. Lastly, the cerebral hemispheres appear to be double from a very early period; but they are probably not so from the very first, for they owe their origin to the extension of a single median part of the wall of the first primary encephalic vesicle together with its ventricular cavity. In fact, the fore and upper part of this vesicle becomes separated from the rest by a cleft or fissure, which, proceeding from behind forwards at each side, cuts off, as it were, the strictly cerebral part in front and above from the thalamencephalal part which remains below and behind.

The extension of the ventricular cavity takes place at what afterwards becomes the foramen of Monro, and is at first only single and median; but as the mass of the cerebral hemispheres rapidly expands outwards and upwards, and comes to be divided into two lateral masses by a partition passing from before backwards, the right and left hemisphere vesicles become distinct, and the ventricular cavity, expanding along with each, comes to form the right and left lateral ventricles, communicating with the third or median ventricle by the single and now reduced foramen of Monro.

In connection with the development of this, which becomes much the largest part of the human brain, the following circumstances are to be noted:—1st, The formation of the anterior and largest basal encephalic ganglia, composed mainly of grey substance, viz., the corpora striata, by a rapid growth of the solid nervous substance in the lower and lateral parts of the commencing hemispheres. These bodies lie chiefly below the expanding lateral ventricles, but to the sides and above, like the thalami, they are in connection with the substance of the cerebral hemispheres by a radiated or fan-shaped expansion of the white nervous tissue, termed corona radiata. These ganglia, like the thalami, are united below, through the crura cerebri, with the hinder parts of the brain. 2nd, A rapid increase of the upper and superficial part of the two hemispheres now takes place, by which their relation to the other parts of the brain comes soon to be greatly changed; for by growing forward they project more and more beyond the region of the first primary vesicle, which, it will be remembered, never advances farther forward than the pituitary fossa (lamina terminalis); while, in expanding upwards, they take the place previously occupied by the mid-brain, and fill the most prominent part of the head; and by a downward and lateral enlargement they form the temporal lobes. Thus frontal, parietal, and temporal lobes come to be distinguishable, and somewhat later, by a farther increase posteriorly, the hindmost parts of the cerebral hemispheres constituting the occipital lobes are formed, and the cerebrum at last covers over completely all the lower parts of the brain. Thus the cerebral hemispheres, which, in the early embryo of all vertebrates temporarily, and in adult fishes permanently, are comparatively small and placed foremost in the linear series of vesicles constituting the fundamental brain, come in man and higher animals to surpass all the other parts in magnitude, and not only to project far before and above them all, but to cover them in completely, so as to hide them from above.

Two sets of connecting bands, between remote parts of the cerebral hemispheres, require to be noticed: one of these, running from before backwards, connects the lower and anterior parts of the cerebrum with the hinder and lateral parts, in the shape of two pillars of white nervous substance, termed the fornix. The other is transverse between the adjacent parts of the cerebral hemispheres, and forms what is called the great commissure, or corpus callosum. This consists of white or fibrous substance in a large mass, which begins to be formed in front, and as the hemispheres grow gradually, extends backwards, so as to unite their inner surfaces, to the extent in the adult of between three and four inches. The fibres of this commissure, which cover in the lateral ventricles, spread themselves in each hemisphere to every part of their wide surface.

Lastly, the expansion of the cerebral hemispheres is attended with the increase of the superficial layer of grey substance, and along with that the division of the upper or expanded part, termed the mantle, into lobes and convolutions.

The upper wall of the vesicular hemispheres is at first quite smooth. The first appearance of division into lobes is that of a blunt notch between the frontal and temporal parts below, in what afterwards becomes the Sylvian fissure. In the fourth and fifth months there appear the vertical fissure separating the parietal and occipital lobes, and the transverse fissure named after Rolando, which divides the frontal and parietal lobes superiorly, and which is peculiarly characteristic of the cerebral type of man and the Simiæ. Another of the earliest furrows appearing in the fœtal brain, is that termed hippocampal, corresponding, on the internal surface of the hemisphere, with the peculiar projection of substance in the ventricle termed hippocampus major.

Thus the great lobes of the cerebral hemispheres, named frontal, parietal, occipital, temporal, and central (island of Reil), are marked off from one another, and by the successive formation of other grooves and the corresponding growth of the cerebral substance between, there gradually follows the formation of the various convolutions, which attain their highest development in the adult human brain; such as the great convolution over the corpus callosum, that surrounding the fissure of Sylvius, the ascending frontal and ascending parietal convolutions, the three series of frontal, occipital, and temporal convolutions, the upper and lower series of parietal convolutions, the annectant, and the various subordinate ones, which come all to be more or less distinctly indicated in the brain by the time of birth. But still they are not fully formed even then, for considerable deepening of the grooves between the convolutions, and further subdivision into subordinate ones, occurs to some extent in the first years of infancy.

We know too little of the progress of minute textural development of the brain substance to enable us to make any statement in regard to this subject which would be of interest. We only know that the brain, like all the other growing parts, is originally formed entirely of cells, that it is by differential transformation of these that the fibrous white substance, as well as the grey cellular constituents of the brain, are produced. Large deposits of grey substance take place in the cerebral ganglia and crura cerebri. The grey substance on the surface is probably the last formed, as we see it increasing considerably in thickness in the last months of fœtal life; and it is probable that the process of textural development continues to go on in the brain, and more especially in its superficial layer, for years after birth. The investigation of the relation between the more complete textural development of the brain and the progress of the intellect, will some day form a most interesting subject of investigation.

The Olfactory Lobes, with which the nerves of smelling are connected, seem at first to come from the anterior and lower part of the cerebral hemispheres, but when the hemispheres have attained a large size, are found to proceed also by a nervous tract from their lower part, in what is called the uncinate convolution. Thus, it appears that the three principal organs of sense are severally connected with three different parts of the fundamental brain, viz.:—1st, The olfactory with the cerebral lobes; 2nd, the optic with the thalamencephalon, and, later, also with the mid-brain; and, 3rd, the auditory with the medulla oblongata.

II. In now proceeding with the second part of my subject—viz., the evolution of the brain in the animal series, it will not be necessary to occupy so long a time as has been spent upon the first, seeing that the differences of its form and structure observed in the various classes and orders of vertebrate animals may be referred to a graduated series of increasing complication proceeding out of the same fundamental type; so that they may be looked upon, in some measure, as a repetition of those which are presented by the embryonic brain of the higher animals in the successive stages of their development.

Thus, in the whole Class of Fishes the brain retains throughout life more or less of the elementary form which is common to the embryo of all vertebrates; that is, it consists of a series of vesicular enlargements of the medullary tube, single or in pairs, extending forwards from the spinal marrow into the cranial cavity.

In the Cyclostomata, such as the Lampreys, the form approaches most nearly to that of the embryo at the period when the five fundamental parts previously referred to come to be distinguished. In such a brain we especially remark the small size of the parts corresponding to the cerebrum and cerebellum, the former being sometimes considerably less than the mid-brain, and the latter being no more than a narrow bridge across the primitive medullary tube.

In the Sharks and Skates there is considerable difference in the relative size of the parts, the cerebral lobes having attained to larger proportions; but still the five fundamental divisions are readily recognised.

In Osseous Fishes some difficulty arises in establishing the homology of the several parts, in consequence of a change in the second and third of the fundamental divisions, which seems to consist in their amalgamation or union, so as to form the large pair of eminences of the brain of these animals, usually named the optic lobes, as well as from the occurrence of additional inferior lobes in connection with them.

But in Osseous, still more than in Cartilaginous Fishes, the cerebral hemispheres are still of very inferior size, and the cerebellum has attained no great magnitude. Thus it happens, that from the small size of the whole brain, and the comparatively large growth of the head, the brain of fishes occupies only a small portion of the space within the cranial cavity.

In the Amphibia we begin to see a manifest enlargement of the cerebral hemispheres in proportion to the other parts (as may be seen from the drawing of the frog's brain exhibited). But yet, though the cerebrum is now the largest part of the brain, and thus hides the second division, it leaves uncovered the next in order of the series of fundamental parts—viz., the mid-brain, which still makes considerable projection, while the cerebellum remains of remarkably small size.

In the class of Reptiles, as in the Turtle (here shown), the proportional increase of the fore-brain has made further progress, and the cerebellum now attains a larger size, especially in its median part; and in the highest members of this class, such as the Crocodile, we perceive the commencement of a transverse grooving of the cerebellum, giving rise to the foliation or laminar division, which is carried much farther in birds and mammals.

The vesicles of the mid-brain, retaining a considerable size, and with a ventricular hollow within each, still remain exposed behind the cerebrum; but the inter-brain is sunk down in the deep cleft between the fore-brain and mid-brain, and is surmounted by the pineal gland.

In Birds, although the vesicles of the mid-brain are still of considerable size, yet, from the great enlargement of the cerebral hemispheres, they now are partially hidden; and from the increase of solid substance within them, their internal cavities or ventricles begin to contract. The cerebral hemispheres now fill the large and expanded vault of the cranium, and a partial division by a blunt notch, indicates the division of the cerebrum into frontal and temporo-parietal parts. The middle part of the cerebellum has also made rapid strides, and is distinctly laminated transversely, and the difference of its internal white and external grey substance becomes apparent. At the sides, too, of the cerebellum additional parts make their appearance in the flocculi, which may be looked upon as the earliest form of the lateral lobes.

As yet there is no pons Varolii, nor any corpus callosum as the great commissure of the cerebrum. The lateral ventricles extend fully within each cerebral hemisphere, and communicate with the third ventricle by the foramen of Monro. In the floor of these cavities are now seen the corpora striata and thalami optici, but there are no posterior lobes of the cerebrum; and it is doubtful if any parts corresponding to the fornix, or hippocampus major, exist. The two corpora striata are united by means of an anterior commissure.

In Mammalia, together with a general enlargement of the cerebral hemispheres, we find now existing a transverse commissure, or corpus callosum, uniting them together, of small size, and confined to the fore-part of the hemispheres in the lower orders—such as the Monotremes and the Marsupiate animals, as well as some Edentata—and gradually increasing in size and extending further and further back in the higher orders as the cerebral hemispheres become more fully developed.

In the lower orders of Mammals the hemispheres are comparatively small and simple, and do not present any division into convolutions, and very little distinction even of the lobes, which are recognised in the higher orders. It is only in this class, therefore, that the cerebral hemispheres, attaining their full development, gradually progress, as it were, backwards, and cover successively the mid-brain, cerebellum, and medulla oblongata, as is found at last in the higher Simiae and in Man. The general expansion of the cerebral hemispheres is attended by a great enlargement of the frontal, parietal, and occipital bones, as well as in part the squamous portion of the temporal bone enclosing the cranial cavity. The development of a posterior lobe only takes place in the higher orders, more especially the Simiae; and in them, too, the proportional enlargement of the frontal lobes brings that part of the cerebrum more and more forward over the nasal cavities and the olfactory bulbs, so that, while these bulbs were at first placed in front of the cerebrum, they come, by relative diminution of size and change of position, to be thrown quite below the frontal part of the hemispheres.

The lateral parts of the cerebellum also undergo a gradual increase in this class; and along with this appears, in gradually increasing size, the pons Varolii, which constitutes, in some measure, a transverse commissure between the opposite sides of the cerebellum.

Along with the corpus callosum or great transverse commissure of the cerebrum, another part makes its appearance in the mammalian brain, and is developed in proportion to its advance in organization. This is the part termed fornix, which lies immediately below the corpus callosum, and constitutes a pair of longitudinal bands, stretching from the hippocampus major and minor of the temporal and occipital lobes on each side forwards in two pillars, which descend into the base of the brain behind the infundibulum into the white projection termed corpus mammillare, or when double in the higher Mammalia, the corpora mammillaria.

The growth of the fornix is accompanied by the formation of the septum lucidum which intervenes between it and the corpus callosum, forms a median separation between the two lateral ventricles, and contains between its two layers the cavity termed the fifth ventricle.

The mid-brain retains the most simple bifid form of the corpora bigemina in the Monotremes and Didelphia, but in all higher animals these bodies are separated by a transverse groove into four, the corpora quadrigemina, of which the anterior pair is usually the largest.

The corpora striata and thalami optici become more fully developed as the cerebral ganglia of Mammalia. The first are united transversely by the anterior commissure, the size of which is generally in inverse proportion to that of the corpus callosum. The thalami are united by the small posterior commissure, and also by the grey commissure, the latter of which, however, is not constant.

With respect to the convoluted condition of the cerebral hemispheres, to which considerable interest is attached from its supposed closer relation to the higher cerebral functions, it appears that, while it is no doubt true that in the main the convolutions become most numerous and deepest in animals belonging to the higher orders, and reach their highest degree of complication in Man and the Anthropoid Apes, there is not any regular gradation of increase to be observed in passing through the whole series of Mammalia, and within each order or large group there may be found very great variations in the degree of convolution. Thus even in the lowest, such as the Monotremes, the greatest difference is observable between the nearly smooth surfaced brain of the Ornithorynchus, and the comparatively highly convoluted brain of the Echidna; and the same may be affirmed of the Marsupial animals; while in the order of Primates it is found that some, as the Marmozet and other Hapalidae, present cerebral hemispheres almost entirely destitute of convolutions, which differ greatly from those of other monkeys, and contrast strongly with the highly developed convolutions of man and the anthropomorphous apes.

Among the other orders of Mammalia, the Edentata, Rodentia, and Insectivora are distinguished by the absence or small size of the convolutions; while in Carnivora, Ruminantia, Pachydermata, and Cetacea, they are moderately or more fully developed.

Anatomists have not yet succeeded in reducing the cerebral convolutions of the different Mammalia to a common type, and it would rather appear that various types or forms of convolutions prevail in different orders or larger groups, as is well illustrated by the selection of drawings of the upper and lateral surfaces of the series of the brains of animals placed before you. Without attempting to trace these differences further, I will here confine my remarks to that type of the convolutions which appears to pervade the whole group of the primates, and which, gradually increasing in complexity, leads to the higher form observed in the human brain.

In its most developed form this plan or type may be briefly described as follows.

Each cerebral hemisphere presents a division into five lobes, which are named the frontal, parietal, temporo-sphenoidal, occipital, and central. In each of these lobes there is a superficial division into convolutions, some of which are principal and others subordinate. In each of the frontal, temporo-sphenoidal, and occipital lobes, we can distinguish three series of convolutions, which are named from their position from above downwards, superior, middle, and inferior; in the central lobe, or island of Reil, there are five or six superficial radial convolutions, and in the parietal lobe a subdivision by the inter-parietal fissure separates the upper and lower parietal lobules, which again are subdivided into convolutions.

Besides these, the following principal convolutions are distinguished, viz.: the ascending frontal and the ascending parietal, situated the one before and the other behind the fissure of Rolando; the callosal and hippocampal convolutions which surround the corpus callosum; and the angular and supramarginal convolutions at the back of the fissure of Sylvius.

To these may be added, as distinguishing peculiarities in the convoluted form of Man and the higher Apes, the cuneus or wedge on the inside of the occipital lobe, and the precuneus or quadrilateral space on the inside of the parietal lobe; and as developed more and more as we rise in the scale of the Simiae, the annectant convolutions which intervene between the parietal and temporo-sphenoidal lobes on the one hand, and the occipital lobes on the other.

Without attempting to trace the varieties of these convolutions throughout the order of Primates, I will only direct your attention to the series of drawings which represent the brains of several apes alongside of those of the Chimpansee and of Man, from which you will easily see that, while in the lowest, such as the Marmozet, there is an almost entire absence of any division of the cerebrum into convolutions, yet in others higher in the scale, as soon as convolutions exist, we can perceive that they are modelled upon the same plan as that which attains its highest development in man. Thus you will observe that in the brain of this Barbary Monkey, familiar to us all, while the fissure of Sylvius divides very clearly the frontal and temporal lobes, there is also present a marked fissure which separates an occipital or posterior lobe from the rest, and that there is also a transverse fissure of Rolando, before and behind which are the ascending frontal and ascending parietal convolutions so peculiarly characteristic of the human brain.

In the three views of the Chimpansee's brain, magnified to three times its natural size—and with which I may mention in passing, the brains of the gorilla and orang agree in a remarkable manner—you will readily see the near approach which is made to the human form in the general development of the convolutions in nearly all the parts, in the complete covering of the cerebellum by the overhanging posterior cerebral lobes, in the double state of the corpora albicantia, the small size of the olfactory lobes, and in many other circumstances which I need not attempt to particularise. The most marked differential character in the brains of the Anthropoid Apes is perhaps in the lower development of the annectant convolutions between the occipital parietal and temporal lobes, and the small number of convolutions in the occipital lobe itself.

III. The gradual increase in the size of the brain, as compared with that of the body, and especially of the cerebrum and cerebellum, which is observed as we rise in the animal scale, has been generally held to bear some intimate proportional relation to a corresponding increase of their nervous and mental endowments. But although in the main this view may be well founded, we shall see that it is subject to many exceptions which are still unexplained. I will now, therefore, under the third division of our subject call your attention very shortly to this difference of size, confining my remarks, however, to the brains of the higher animals and of man.

Information as to the size of brains might, of course, be obtained most directly by actual measurement of their dimensions and weight; but, as this is often difficult, we have recourse also to the measurement of the capacity of the cranium, the cavity of which is completely filled by the brain and its accessories in all the higher animals.

I shall be able to illustrate the difference of brain size, as ascertained in the last-mentioned way, by reference to a number of casts, now shown, of the cranial cavity in different animals and races of man, which are a selection from those made for the Museum of the College of Surgeons, London, and which I have placed in the Hunterian Museum of our University; and, in connection with this, I refer you also to the short tabular statement which is placed before you, in which the brain weight and cranial capacity, and their relation to the weight of the body, are compared in man and a few animals (see p. 34).

To begin with my remarks on the size of the human brain, it may be stated as the result of an extended inquiry over several thousand skulls made by different observers, that the cranial capacity is on the whole greater among the highly civilised than among the savage races, and that there is even a very manifest difference to be found among persons belonging to the same race, between the crania of persons of higher mental cultivation and acknowledged ability and those of the uneducated class and of inferior intellectual powers.

The amount of this difference is as yet only imperfectly known, and has sometimes been over-estimated by those who have adopted strong pre-conceived views on the subject; but, making due allowance for the chances of error, it may be stated as probably amounting to from 5 to 7½ per cent. in persons of the same race, and to about double that range in those of different races.

Thus, the average adult brain of men of this country being taken at 3 lbs., or, more precisely, at 49½ oz. avoir.,* at an average specific gravity of 1040, this would give a bulk of 82·5 cubic inches of brain substance; and if we make an addition of 10 per cent. for loss by membranes, fluid, &c., the cranial capacity for such a brain may be calculated at about 90 cubic inches, and conversely we may calculate the bulk and weight of the brain from the known cranial capacity. If, therefore, the brain of the uneducated class falls 2·5 oz. below the average, while that of the more cultivated persons rises to the same amount above it, or to 52 oz., we may estimate these brain sizes as corresponding respectively with brain bulks of 78 and 87 cubic inches, and with cranial capacities of about 88 and 97 cubic inches.

If, again, we compare the average brains of the European races with those of the lowest savages, such as the Australians, we shall find the latter to be of an average weight of 42 oz., and to correspond with a brain bulk of about 70 cubic inches, and a cranial capacity of about 78 cubic inches.

But there are examples outside the averages in all races of very considerable variations in brain-size and cranial capacity, although the range of these extreme variations differs like the averages themselves in different races. Thus there have been known brains belonging to persons of the European races of the weight of 60, or even as high as 65 oz. avoir., as in the well-known instance of Cuvier the great naturalist, and this would correspond to a brain bulk of 108 cubic inches, and a cranial capacity of 118 cubic inches; while, on the other hand, it is found, even among the European races, that the weight of the brain has fallen as low as 32 oz. (the lowest probably compatible with healthy action), which would correspond to a brain bulk of 53 cubic inches, and a cranial capacity of about 63 cubic inches.

These very great variations in brain size are in a great measure, though not altogether, independent of differences of stature in the whole body; and it must be regarded as a remarkable fact, not yet fully understood, that an organ constituted as the brain is should, in different members of the same species, be subject to so great a range of difference as that in some cases it should be double the size that it is in others.

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* The average weight of the female brain in this country is about 44 or 44½ oz.

The brains of the Anthropoid Apes, the Gorilla, the Chimpansee, and Orang, all of which have now been well described by competent authors, are far inferior to that of man in their dimensions. Even in the Gorilla, which is most similar in stature to man, the brain does not attain more than a third of the weight of the average human brain, and in the Chimpansee and Orang it does not even reach a fourth; and thus in these animals the proportion of the weight of the brain to that of the whole body may be as one to a hundred, or even lower, while the proportion in man is from 1 to 40 to 1 to 50.

In most other animals the proportion, as a general rule, is still lower, and in some indeed very much inferior to that before stated. But here it is proper to state a remarkable fact which has been derived from a consideration of this proportion throughout a wide series of animals—viz., that in general among the largest animals of any order or group the brain does not reach a size which is by any means proportionate to the greater magnitude of the other organs or of the whole body, so that in the smaller members of the same order or group, a considerably greater proportional size of the brain is observed. This fact obtains even in the order of Primates, with man at its head, as is very well illustrated by the example of some of the smallest monkeys, in which, as I and others have found in the Marmozet, the brain holds the proportion of one-twentieth of the weight of the body, or more than double the proportion existing in man.

As a very striking further illustration of the same fact, I may refer to the Whale and the Porpoise in the order Cetacea. Here, for example, is the cast of the brain of a Greenland Whale, which was 75 feet in length, and whose weight could not, at the lowest computation, have been less than 60 tons, and yet the brain only weighed about 6 lbs., or twice the weight of the human brain, thus giving a proportion of brain to body of 1 to 22,600; while the common Porpoise, or Cetacean of our seas, weighing probably not more than 60 lbs., has a brain, of which I now show you the cast, of the weight of 1 lb. or 16 oz., and consequently giving the enormously superior proportion of one-sixtieth. I may add that both of these brains, but more especially that of the Porpoise, is very fully convoluted.

Among the Pachydermata, too, examples of the same contrast are to be found. Thus the brain of the Elephant, which weighs three times as much as that of man, and is, in fact, the largest brain known among animals, and is very fully convoluted, is yet, from the very great size of the animal, which we may estimate at three or four tons, in a much smaller proportion to the weight of the body than is that of the Pig or other smaller members of the order.

So, too, in the Dog tribe, we shall find that the smallest races have the largest brains in proportion to the body, as may be seen from the two examples noted in the table, in the smaller of which the proportion is the same as in man, while in the larger it is reduced to at least one-third.

The same general fact has long been known in the class of birds, in the smallest of which, such as the Linnets and Finches, the proportion of the brain to the body frequently rises as high as or above one-twentieth.

It must be confessed that we are as yet wholly unacquainted with the significance of this very remarkable fact; and therefore, although it may be to some extent true that, within certain races of man and certain species of animals, the size of the brain varies in proportion to the mental capacity and activity of the central nervous functions, yet it is obvious that we cannot, in the present state of our knowledge, place implicit reliance on size alone as a criterion of perfection of function in the brain.

It is necessary, also, to keep in mind another general fact with respect to the size of the brain and its proportion to the body, viz., that in the young of man and of animals generally, as the brain grows more rapidly than the rest of the body, or is, as it were, more advanced in its development, it necessarily bears a much larger proportion to the body in the fœtus and in early youth, than it does in the adult. In comparing, for example, the skulls of children with those of adults, and those of a young Orang and a young Chimpansee with others which are fully grown, one cannot fail to perceive the very great difference existing between them in the proportion of the cranium and face, and this depends not only on the large size which the cranium containing the brain has early attained, but also on the inferiority in the development of the jaws and other parts of the face.

The brain of a male child at birth weighs, on an average, nearly three quarters of a pound, or 12 oz.; and if we assume the average weight of the child to be 7½ lbs., or 120 oz., the proportion will be seen to be a tenth. And so rapidly does the brain continue to grow during the early years of childhood, that already by the age of three years it has attained more than three-fourths of its full size; by the age of seven years it has reached the proportion of nine-tenths, and after this, only by slow and comparatively small gradations, it attains the full size between the age of twenty and twenty-five years.

The same precocity of growth in the brain exists among animals in general, as may be seen by reference to the specimens now shown of the young Gorilla, Orang, and Chimpansee skulls; and it is obvious therefore that, in any comparison of the size of brains from the capacity of skulls or otherwise, account must be taken of the age (as well as the sex) of the animals compared.

The relation of the size of the brain to the defect of idiocy is a subject of considerable interest, but time does not admit of my treating it in detail. It is true that there are many instances of idiots in whom the brain has either been of the full average size, or not more below it than occurs in many sane persons. But this need not create surprise when we consider that the functions of the brain may be disordered, and even abolished, by pathological changes of its intimate structure, and that these are sometimes so minute as to escape very close observation. There are, however, other examples, more especially of congenital idiocy, which are coincident with marked inferiority of size, and (as may be seen from one of the drawings presented) with want of due development of the normal cerebral form. It would appear that in general, throughout the human race, no brain under 30 oz. is sufficient for the exercise of its normal functions.

Some of the more remarkable of the relations referred to in the foregoing pages are illustrated by the annexed table:—

TABLE SHOWING SOME EXAMPLES OF THE COMPARATIVE SIZE OF THE BRAIN AND BODY.

Examples.	Brain-weight in oz. avoir.	Internal Cranial Bulk in cub. in.	Whole Weight of the Body in lbs.	Proportion of Brain to Body-weight.
Average European Man,	(3 lbs.) 48	85—88	140	1 to 46
Child at Birth,	12	22	7½	... 10
Chimpansee,	10	19	50	... 80
Marmozet,	⅓	½	6 oz.	... 20
Middle-sized Dog,	3½	6	36	... 164
Small Dog,	2½	4½	7	... 45
Elephant,	(9 lbs.) 144	300	(3 tons) 6720	... 750
Pig,	6	11	94	... 250
Whale,	(6 lbs.) 96	650*	(60 tons) 134,400	... 22,600
Porpoise,	16	30	60	... 60

* The large cranial bulk in this instance is connected with the enormous size of the roots of the cranial nerves.

IV. In proceeding now to consider, in the fourth place, the relation subsisting between the minute structure of the brain and the manifestation of its functions, or what may be termed the more immediate mechanism of cerebral action, we have to grapple with much the most difficult part of our subject. To attain to a comprehension of this mechanism, the results of physiological experiment and pathological observation must be combined with full and accurate knowledge of the anatomy; but, unfortunately, the investigation of the minute cerebral structure, notwithstanding the great amount of attention recently bestowed upon it by the most competent workers, has not yet led to very definite results; nor have the anatomical facts observed been found to be in entire accordance with the data hitherto supplied from physiological and pathological sources. I must content myself, therefore, with the briefest possible treatment of this part of our subject.

Referring to what was stated in an earlier part of this lecture, it will be remembered that the brain and spinal marrow, as central nervous organs, consist essentially of two very different forms of nerve tissue, viz., the white or fibrous, and the grey or cellular, the first of these being composed of distinct longitudinal fibres, in many respects similar to those of which the peripheral nerves are formed; the other always containing, along with fine interlaced fibres, peculiar corpuscles or cells, which belong almost exclusively to the central nerve organs, and are in some intimate connection with the nerve fibres.

As might be supposed, the office of these two kinds of nervous substance is very different, and yet their concurrence is necessary to the manifestation of almost all kinds of nervous phenomena in the animal body. It is universally admitted by physiologists that the fibrous element, whether existing in the central organs or in the peripheral nerves, is essentially a transmitting medium, or, in other words, that the change which we call nervous action, induced by a stimulus or excitement in a living nerve, is conveyed or conducted along each individual fibre separately, from one end to the other, so long as it holds an uninterrupted course. We do not know, any more than in the case of a galvanic wire, the intimate nature of the process by which the conduction is effected; and it seems not improbable that nerve fibres may, like galvanic wires, be capable of transmitting their action in both directions equally: but in ordinary circumstances the direction of a nerve current can be recognised only from the effect resulting. Thus, in the efferent or motor nerves, the outward conduction of the excitement is immediately indicated by the muscular contraction which follows; while in the case of the afferent or sensory nerves, the course inwards is manifested by the less direct succession of sensation, or by the transference of the nervous influence through central nerve-cells to motor fibres, so as to give rise to reflex muscular contraction. Nor has any characteristic difference in structure been ascertained to exist between the fibres of sensory and motory nerves; it is only known that the former are, on an average, somewhat less in diameter than the latter.

The corpuscles or cells of the central grey substance, with which many of the nerve fibres are undoubtedly united in a more or less direct manner, have obviously a very different function from that of mere conduction; but as to the nature of nerve-cell action, we can only form very vague conjectures. The structure also of the grey substance is as yet very imperfectly known. There are probably various forms of it in different parts of the central organs, but in the main they all agree in possessing the characteristic cellular constitution; the cells being mingled as well as united with a variable quantity of nerve fibres, and with finely granular or molecular substance, and the whole being set in a matrix of delicate reticulated connective tissue, permeated by blood-vessels, from which are derived the nutritive materials for the maintenance of the chemico-vital changes which are associated with the nervous as with all living actions.

In the simplest example of a central nerve action, viz., that of the transference or conversion of an afferent into a motor impulse, which leads to reflex movement, there can be little doubt that it is by the union established between the two kinds of nerve fibres concerned, by means of the radiating processes of the intervening cells, that the transference is effected; and we have every reason to believe that even in the very complicated automatic or involuntary movements involved in many of our actions, which may go on independently of consciousness, it is entirely by a similar, though doubtless a more complex arrangement of cellular intervention between nerves of different endowments, that the muscles are set in motion.

We do not know, it is true, whether this process of transference is simply one of conduction or something more; but in the more complex forms of central nerve action, if not even in the most simple, it seems probable that the cells are capable of increasing or modifying nerve force, or possibly of initiating it within themselves, as well as of transmitting and transforming that which has been brought to them from without; and we are still more in the dark in regard to that peculiar form of nerve action which is called inhibition.

It is well known that habit or frequent repetition may have the effect both of rendering certain channels of communication or transference more easy, and certain actions more ready to recur, and possibly of establishing new channels not originally existing; but the nature of the instinctive movements which occur in the first acts of the child after birth, such as the first respiration, sucking, crying, and the like, are sufficient proof of an originally existing nervous mechanism, or rather a series of such mechanisms of wonderful complexity, which provides for the natural occurrence of these movements by the reaction of parts of the nervous system on each other, and altogether independently of the will.

Little as we know these mechanisms, however, beyond the certain fact of their existence, it is far more difficult to comprehend in what manner the relation is established between cerebral structure and the higher psychical phenomena of conscious sensation and perception, ideas in their simple and their abstract form, memory, judgment, and volition. And yet physiology and pathology point out in the most unmistakable manner the immediate dependence of them all on cerebral action as a physiological condition.

If this view be admitted, we shall further be disposed to recognise a more close relation of psychical phenomena to the cells of the grey substance than to the fibres of the white, and more especially to the peculiarly-formed cells of the layer of grey matter which covers the surface of the cerebrum and its convolutions, as the more immediate seat of the purely mental processes.

The investigation of the structure of parts so highly endowed must therefore be looked upon as one of the most interesting problems presented by the whole range of anatomy, and no doubt it is one which will engage the attention of men of science during many years to come, with what result, however hopeful I may be, it is not for me to attempt at present to determine.

I will rather endeavour, as briefly as possible, to explain the most important facts which anatomy has brought to light respecting the structure of the brain in illustration of its functions.

Taking the simplest and most general view of the structure of the several parts of the cerebro-spinal nervous system in its relation to their functions, we may look upon the whole arrangement as one fitted to bring the external or peripheral organs for the reception of sensory impressions, and the production of motions, into connection with the central organ or brain, and ultimately with its superficial covering ot grey substance in which its highest functions are elaborated. This is effected by a succession of conducting channels of fibrous nerve substance, and connecting or interrupting masses of grey matter which lie between the opposite termini of the system, and which may be brought under the three following categories, viz.:—1st, Those which are next the peripheral organs, comprising the sensory and motory nerves, all of which are connected at their roots with grey substance in the spinal marrow or brain; 2nd, those which intervene between the nerve roots and the central cerebral ganglia, including the cerebral and cerebellar peduncles or stems, and the deep masses of grey substance which occupy the ganglia and other situations in this division of the system; and 3rd, the spreading fibres which, emerging from the ganglia and deeper parts of the brain, expand in the cerebral hemispheres till they reach and combine with the grey substance of the surface and its convolutions.

1. With respect to the first division of these parts, as the

description of the structure of the nerves does not belong to my present subject, I will only remark that, assuming that the root-fibres of the nerves are all connected with grey substance at their central origin, and that none pass directly inwards to the brain without such intervention, we may regard this grey matter to be the means not only of connecting together nerve fibres of different endowments, so as to favour their mutual interaction, but also of transferring nervous influences from or to the next set of channels of communication between the brain and the peripheral organs.

2. The second set of parts in this system, situated between the grey matter which gives origin to the various nerves and the deeper parts of the brain, differ very much in the spinal marrow and in the brain itself; consisting, in the first, of comparatively simple tracts of white fibrous substance, but in the latter attaining much greater complexity, as they are prolonged onwards through the medulla oblongata, and are reinforced by new additions in the pons Varolii and cerebral and cerebellar peduncles, before they reach their upper limits in the grey substance of the cerebral ganglia.

In the spinal marrow the whole of the white substance by which nervous influences are mainly carried upwards, is arranged so as to form the anterior, lateral, and posterior columns, in all of which (and especially in the lateral) the direction of the nerve fibres is mainly longitudinal. Although doubts still prevail among physiologists as to the exact course taken by sensory impressions and motor influences through the cord, it may be stated as most probable that motor influences pass downwards in the fore-part of the lateral columns, and perhaps also in part in the anterior columns; while sensitive impressions are conveyed upwards in the hinder part of the lateral columns, and perhaps also in part in the internal grey substance and in the posterior columns. And it may be stated, that in these last-mentioned parts the nerve fibres are on the whole much smaller than in the fore-part of the lateral, or in the anterior columns.

Here, too, must be noted the important fact resulting from physiological experiment—that, while motor influences descend through the columns of the cord on the same side as the roots of the nerves upon which they act, sensory impressions (at least those of pain and touch) ascend on the opposite side from that on which the posterior or sensory roots have entered. Thus it appears that the most of the fibres in communication with those of the sensory roots cross at once to the opposite side of the cord, as may indeed be seen in the grey commissure, while the motor fibres remain on the same side. But at the upper part of the spinal marrow, or rather when they have just entered the medulla oblongata, the motor columns suddenly cross, in more or less divided bundles of fibres, from one side to the other. This occurs in the so-called decussation of the pyramids, which consists essentially in the oblique passage across the middle plane of a considerable part of the lateral columns of the cord, containing its chief motor fibres, into the opposite anterior pyramids of the medulla oblongata. Thus, as is well known from pathological observations and physiological experiments, the effect of deep-seated injury of the brain on one side is always manifested by more or less widely-spread palsy—that is, loss of motor or of sensory power, or of both, on the opposite side of the body.

The increase and modification which the ascending columns of the spinal marrow undergo as they are prolonged into the medulla oblongata, may be shortly explained as follows :—

a. The anterior spinal columns, being thrust aside by the intervention of the pyramids, become the olivary columns of the oblong medulla, and contain within them the dentated nucleus of the olivary body, the cells of which appear to be a source of new fibres, which pass across between the bodies of opposite sides, and from each also into the cerebellar peduncles of the opposite side. The main part of the olivary columns passing deeply through the pons Varolii are continued up into the corpora quadrigemina as the fillet. The properties of this nervous tract are not well known ; but, seeing that the anterior spinal columns are intimately connected with the motor nerve roots, and the corpora quadrigemina with vision, a conjecture may be hazarded, that through them are regulated the motions of the body which are dependent upon guidance by sight.

b. The anterior pyramids, which are the prolongations of the decussated motor part of the lateral spinal columns, ascend through the pons Varolii at a small depth from its anterior surface, and form the lower part, or crust, of the crura cerebri. Thence they penetrate for the most part the corpora striata, and are believed to be connected with its grey nuclei, more especially the nucleus lenticularis. It is doubtful whether any of its fibres pass into the cerebral hemispheres without having been previously united with grey substance.

c. The upper part of the cerebral peduncle differs greatly from the lower in having its fibres much intermixed with grey substance. It consists mainly of fibres prolonged upwards from a part, probably the sensory part, of the lateral column of the spinal marrow, together with a portion of the posterior column, and it is generally regarded as a channel of sensory conduction. Along with the foregoing, it receives from behind an accession in the processus a cerebello ad cerebrum, and a part of the combined fibres may pass into the corpora quadrigemina lying immediately above the crura cerebri.

d. The remaining parts of the spinal medullary columns, consisting of a large portion of the posterior, together with offsets from the lateral and anterior columns, enter into the formation of the restiform body or inferior peduncle of the cerebellum, into which its fibres spread towards the surface, along with the other fibres which enter that body from its superior or cerebral peduncles and from the pons Varolii. The last-mentioned body, which appears to be developed in proportion to the size of the lateral masses of the cerebellum, is composed mainly of transverse fibres as it enters the cerebellum and forms the middle peduncles of that body on the two sides. Crossing from side to side below, and imbedding the longitudinal columns which pass from the medulla oblongata into the crura cerebri, it appears at first sight to be mainly a transverse commissure of the cerebellum; but its fibres are much intermingled with grey substance, and undergo decussation in such a way that they are considered to establish communication between the cruri cerebri of one side, and the opposite side of the cerebellum.

The several parts of the great cerebral stalk or peduncle may be considered to terminate in or lead to the various masses of grey substance occupying the interior of the so-called cerebral ganglia; the white fibres of the crust, or lower part, proceeding most directly to the corpus striatum, those of the tegmentum, or upper part, to the thalami and corpora quadrigemina; and it is now generally believed that the greater number of the motor fibres are collected in the crust, while the tegmentum contains a preponderance of sensory fibres. In connection with this view, it is also held, on pathological as well as on physiological grounds, that the corpora striata are the great centres of motor impulses; the thalami and corpora quadrigemina the principal seats of the arrival of sensory impressions, and of their reaction on the motor centres of all the automatic actions.

It is indeed certain that animals deprived of their cerebral hemispheres are still possessed of some sensory faculty, and capable, under excitement, of many purposive movements of great complexity, even when a part only of the cerebral ganglia remains entire, although they are altogether without voluntary power or spontaneity of action.

3. The third and highest division of the parts of the brain now under consideration comprises the large mass of medullary fibres which extend from the upper confines of the cerebral ganglia into the covering capsule of grey matter by which the convoluted surface of the cerebrum is everywhere surrounded. This forms the corona radiata of authors, and has the form of a fan or brush-like expansion of fibres, which stretch from the outer and upper sides of the corpora striata and optic thalami into the centres of the convolutions, penetrating into and intimately uniting with the superficial grey substance.

Upon the supposition that the will and other mental operations are exercised in connection with the active condition of the superficial covering of grey matter, it is conceived that the peculiar hastate or spear-like corpuscles or cells which occupy this substance in several successive layers, and with which undoubtedly the terminal nerve fibres are in some way united, are the more immediate seat of the nervous action by which these operations are evolved. But we must confess ourselves profoundly ignorant as to the nature of this action and of the share very probably taken in it by the different structural elements which are associated in the composition of the grey substance.

For the production of conscious sensation or perception, we may suppose that the sensory impressions which have been carried from the periphery as far as the thalamus, or other great sensory centre, should be there transferred to certain fibres of the corona radiata, and conveyed by them to some part of the superficial grey substance in which they produce determinate changes; and that, for the formation of ideas and judgments, there shall occur the various combination of such conscious perceptions, with the psychical changes following on the consequent cerebral actions in one or other part of the covering grey layer of the brain.

These perceptions, ideas, and judgments leave certain impressions on the structural elements, by the action of which they have been evolved, which, though in abeyance when these elements are not in an active state, are capable of being re-excited or recalled in the process of memory.

So also, under the influence of present conscious perceptions, ideas, and judgments, as well as of their reproduction by memory, there may be excited, in connection with one or other part of the cerebral cortex, those impulses to which we give the name of will, which, when directed outwards on the motor mechanism of the ganglia and nervous channels, lead to all our active movements by the induced contraction of the muscles.

We are, however, still ignorant whether these faculties and powers result from an action which pervades the whole or any part indifferently of the superficial cerebral substance, or whether it may be possible to localise their various forms as depending upon the nervous activity of distinct portions of the brain. Although the well-known phrenological system has failed to produce the proofs satisfactory to physiologists which its votaries anticipated for it, there are many facts ascertained from pathological observation, and from the recent experimental researches of Hitzig, Ferrier, and others, which indicate with great probability that certain regions of the superficial grey covering of the brain are more immediately connected than others with the excitement of motions and the reception of sensations; and the view gains ground that there are also certain parts of the cerebral cortex with which the several psychical processes are specially related.

The fibrous parts now described as extending in two stages between the motor and sensory nerves on the one hand and the surface of the brain on the other, have been named the peduncular system, to distinguish them from two other sets of fibres which form important constituents of the cerebral structures—viz., the commissural and the collateral sets of fibres.

The commissures consist of fibres which, passing across the middle plane, bring into union and consentaneous action corresponding parts on the right and left sides of the brain. The largest mass of this kind is the corpus callosum, or great cerebral commissure, the fibres of which accompany those of the corona radiata in their expansion into the hemispheres and their convoluted surface so closely, that it is almost impossible to distinguish between the peduncular and the commissural fibres after they have become associated together. The anterior and posterior white commissures and the grey commissure similarly unite opposite parts of the hemispheres, and the pons Varolii is probably, at least in part, a commissure of the two lateral halves of the cerebellum.

Thus, too, it appears that the brain, as regards its most superficial part and highest psychical operations, is in some measure a double organ, while the action of the cerebral ganglia is almost entirely unilateral.

There are several remarkable pathological observations which prove that the mind may still remain entire notwithstanding the removal of large portions of the upper part of the brain of one side. The history of the remarkable affection termed Aphasia is a good illustration of the cross and the unilateral action of a part of the brain.

In the great majority of cases of this morbid condition, while the persons retain more or less, and sometimes very perfectly, their knowledge of the meaning of words as well as their general intelligence, they have lost the power of expressing ideas in speech, without, however, any impairment of the power or control over the muscles of the organs of voice or articulation, or even the ability to repeat words spoken by another; while, at the same time, they are affected with paralysis of one or both limbs, and that almost always on the right side of the body. Now, in these instances, according to the discovery of the French pathologist, M. Broca, the lesion or disease of the brain is found to be situated in the back part of the third or lowest frontal convolution, just at the entrance to the fissure of Sylvius. And thus in the affection of Aphasia we have combined a unilateral superficial cerebral lesion, with opposite unilateral palsy of the body, and an interference with a process which consists more immediately in the excitement of a bilateral motor mechanism for the conversion of ideas into spoken or written language: and yet, in some strange and inexplicable manner, this mechanism seems to be excitable only from one side, while the upper part of the brain, so far as the ideas and the will are concerned, seems to be capable of working equally by either side.

The connection between different parts of the brain on the same side is established by means of the third set of fibres to which I have referred—viz., the collateral longitudinal or associating, the nature and uses of which are even less known than those of the other two sets previously described.

The fornix is one of the parts belonging to this system, and seems to connect the hippocampi of the middle and posterior lobes with the thalami optici, through the curious twisted course of its anterior pillars in the corpora albicantia. The taenia semicircularis, the longitudinal striae of the corpus callosum, the fibres running along the convolution of that body, and the uncinate fasciculus, are other instances of bands of fibres confined to one side, and serving apparently to unite different parts of the brain, but in a manner and for purposes which are still wholly unknown. The fibres which pass from convolution to convolution in the bottom of the grooves between them may be brought under the same division, and may be looked upon as the probable means of connecting together different parts of the grey covering of the brain, of combining, therefore, possibly sensations, ideas, voluntary impulses, or other psychical operations which may belong to different regions of that part of the cerebral organization.

Lastly, the expanded portion of the cerebellum, which attains a considerable size in man and the higher animals, presents a structure in some respects comparable to the convoluted part of the cerebral hemispheres. A layer of grey matter, containing cells of two kinds, covers the whole outer surface, and is thrown into inflections of a plated or foliated form, so as greatly to increase its extent, just as is caused by the convoluted form in the superficial part of the cerebrum. The interior of the plates is occupied by an extension of the fibrous white substance formed by the expansion of the combined fibres of the three peduncles before referred to, and somewhat in the same manner as in the cerebrum, the fibres of the deeper white substance of the cerebellum enter into communication with the larger branched cells of the grey substance.

By means of the lower peduncle fibres are carried into the cerebellum from the several columns of the spinal cord, those of a sensory kind appearing to predominate; by the superior peduncles the fibres of the cerebellum are made to join superiorly the tegmentum of the crus cerebri, and perhaps also the corpora quadrigemina; while the pons Varolii seems to unite the opposite halves of the cerebellum below, and to establish other unions between its stem and the roots of the cerebral and spinal nerves.

The cerebellum does not appear to exercise any important function in connection with sensation, volition, or intellect, but experimental evidence indicates that it has some close relation to the co-ordination of voluntary movements. The mode of its operation, or the relation of its structure to this or any other function, is still whollv unknown.

In the preceding slight sketch of the minute structure of the brain, from which I have been obliged by want of time to omit all details, I have endeavoured to show how intimately the various processes which make up our sentient, percipient, active and intelligent nature are associated with an organization of the most delicate, complicated, and refined description; and how closely the advance in the development of nervous and mental powers follows the advance in the perfection of structure in the bodily organ, in the first formation of the being and its subsequent progress to maturity, as well as in all the varying conditions of animal life. I by no means wish to be understood to contend that our knowledge, either of nervous phenomena or of the structure of nervous organs, is yet such as to warrant dogmatic assertion of an indissoluble and direct relation between organization and mind; but I venture to affirm that, if we deal with this problem in the same manner as with other scientific investigations, we cannot arrive at any other conclusion than that mental processes, however complicated they may become in their higher forms, have taken their first origin in nervous action resulting from the vital activity of nervous structure, and that their rise into higher and higher forms of psychical phenomena is only a fuller development and closer combination of repeated and more complicated nervous actions.

I would here remark that, although a mechanism be of organic nature, and subject to the complex and varying conditions of a living organization, the phenomena which result from its activity are not less the immediate product of its internal changes than are those of the evolution of heat, light, electricity, and magnetism, from the bodies with which these forces or states of inorganic matter are observed to be associated. We do not know nerve force as distinct from the nervous fibre. We have good reason to believe that by some modification of that force in its passage through the nerve-cell, an afferent nervous impression is converted into an efferent impulse in the phenomenon of reflex action. And it does no violence to our power of conception to extend the same view to the more complex mechanism situated within the cerebral ganglia, by which all those motions which we style automatic appear to be regulated without the co-operation or control of will or intelligence. When, however, the same afferent impression, which causes a simple reflex or a more complicated automatic motion, reaches the higher part of the brain and results in sensation or perception, what grounds have we, on any physiological or scientific principle, for asserting that the change which follows is other than a higher manifestation of some nervous property?

As physiologists we know of the exercise of mind only in its association with the brain, as a part of our organization in a state of integrity, and in the conditions of life ascertained to be necessary to the manifestation of its action. Surely the intelligent part of our nature, if in itself noble and elevated, can suffer no degradation from its corporeal origin being ascertained. Rather might we say that the corporeal organization gains in dignity by the proof of its association with the nobler principles of our nature; and that the sciences which profess to investigate the relation between cerebral organization and mental phenomena, thus become entitled to the highest rank among the attainments of human knowledge.

The dignity or elevation of any branch of knowledge will obviously depend mainly upon the character given to it by those who inquire into it; and if, upon sufficient evidence, the unbiassed judgment of science arrives at the conclusion that the operations of the mind are the result of the vital activity of cerebral organization, it neither alters in any respect the real essence of mind as distinguished from matter, nor does it detract in the least from the greatness of its powers. While, on the other hand, the careful study and increased knowledge of the relation between mind and body may be the means of making us better acquainted with the nature of our mental powers, and may lead to useful practical improvement in their cultivation. We cannot doubt, at all events, that a healthy organization, and an observance of sanitary laws of life, are necessary to the evolution of the best mental efforts; and it is no less certain that hereditary influence is equally powerful with educational culture in carrying our mental powers to their highest state of perfection.

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